CALIBRATION OF A BRIDGE WIRE

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Abstract

For the calibration of a bridge wire various methods have been devised, most of which have the same equivalent Wheat-stone network (Fig. 2). Of the variety of methods employed, the method of calibration due to Carey-foster is the best. The following paper gives an account of a modification in the experimental arrangement which has the same equivalent network as in Careyfoster's method, but with the following alterations: (1) A low resistance rheostat replaces the second bridge wire or the resistance boxes P and Q employed in some of the methods; (2) The resistances M and N are not bodily removed and interchanged between the two outer gaps; but the transfer from the one gap to the other is accomplished by a mercury cup switching device.[1] These modifications ensure compactness, rapidity and accuracy in the calibration of the bridge wire. The modifications also permit the gauge piece being enclosed in a uniform temperature bath thus eliminating any possible small error due to thermal effects. A set of observations taken with a bridge wire according to the method suggested bear ample testimony to the efficacy of the method suggested.

Theoretical Considerations

Let P and Q be the resistances in the inner gaps of the bridge and M and N the resistances in the outer gaps. Let us investigate the values of the ratio P/Q, during consecutive steps in the calibration of the bridge wire. Let R be the resistance and L cm. the length of the bridge wire AB (Fig. 1). If it is desired to calibrate the bridge wire in n steps, a gauge piece M whose resistance is equal to $\frac{R}{n}$ must be constructed for the purpose. N is a thick copper strip of negligible resistance.

First step (*a*): Let P_1/Q_1 be the resistance ratio in the inner gaps to obtain a balance with the sliding contact at the zero of the bridge wire, when the resistances M and N are as shown in the figure. Then

$$\frac{P_1}{Q_1}=\frac{M+O}{N+R}=\frac{R/n+O}{O+R}=\frac{1}{n}. \tag{1}$$

First step (*b*): M and N are now interchanged and the new balance point is found without altering the ratio P_1/Q_1. Let the balance be obtained at a distance of l cm. from the zero end of the bridge wire. Then,

$$\frac{P_1}{Q_1}=\frac{N+l\cdot\frac{R}{L}}{M+(L-l)\frac{R}{L}}$$

or
$$\frac{P_1}{Q_1}=\frac{O+l\cdot\frac{R}{L}}{\frac{R}{n}+(L-l)\frac{R}{L}}$$

or
$$\frac{P_1}{Q_1}=\frac{nl}{L+(L-l)\,n}$$

Substituting for $\frac{P_1}{Q_1}$ from equation (1), in the above, we have $\frac{1}{n}=\frac{nl}{L+(L-l)\,n}$ which on solving gives $l=\frac{L}{n}\cdot$

Second step (*a*): The next step in the calibration consists in altering M and N to their original positions and finding the ratio P_2/Q_2 so as to obtain a balance at the same point which is at a distance of l cm. from the zero end of the wire.

$$\frac{P_2}{Q_2}=\frac{M+l.\frac{R}{L}}{N+(L-l)\frac{R}{L}}.$$

Substituting for l, M and N, we have:

$$\frac{P_2}{Q_2}=\frac{\frac{R}{n}+\frac{L}{n}\cdot\frac{R}{L}}{O+\left(L-\frac{L}{n}\right)\frac{R}{L}}=\frac{2\,\frac{R}{n}}{R\left(1-\frac{1}{n}\right)}$$

or
$$\frac{P_2}{Q_2}=\frac{2}{(n-1)}. \tag{2}$$

The process (*b*) is repeated and the balance point is found. If the wire is uniform, the null point will occur at $2\,l$ cm.

Third step (*a*): Let us evaluate the ratio $\frac{P_3}{Q_3}$ in the third step.

$\frac{P_3}{Q_3}=\frac{M+2l\cdot\frac{R}{L}}{N+\left(L-2l\right)\frac{R}{L}}$; substituting for l, M and N as before, we have:

$$\frac{P_3}{Q_3}=\frac{\frac{R}{n}+2\frac{L}{n}\cdot\frac{R}{L}}{O+\left(L-\frac{2L}{n}\right)\frac{R}{L}}=\frac{3\frac{R}{n}}{R\left(1-\frac{2}{n}\right)}$$

or

$$\frac{P_3}{Q_3}=\frac{3}{n-2} \qquad (3)$$

and so on.

We thus have for the ratio $\frac{P}{Q}$, the values: $\frac{1}{n}, \frac{2}{n-1}, \frac{3}{n-2}, \ldots\ldots\frac{n}{1}$, during the consecutive steps in the calibration of a uniform wire. In any actual case these values represent the ratios approximately. The decrease in the resistance in one of the ratio arms is equal to the increase in resistance of the other ratio arm. The use of a rheostat in the manner shown in the diagram easily enables us to secure this adjustment.

Experimental Arrangement

The arrangement of apparatus actually employed in the calibration of the bridge wire A B is shown in Fig. 1. The end terminals of the rheostat are connected to the terminals *d* and *e* of the inner gaps. The sliding contact terminal of the rheostat is connected to *b*. The terminal *b* is also connected to the galvanometer. The other terminal of the galvanometer is connected to the sliding contact. The battery is connected in the usual way as shown in the diagram. 1, 2, 3, 4, 5, 6 are six cups containing mercury symmetrically located in a paraffin block. Connection to the cups can be made by terminals

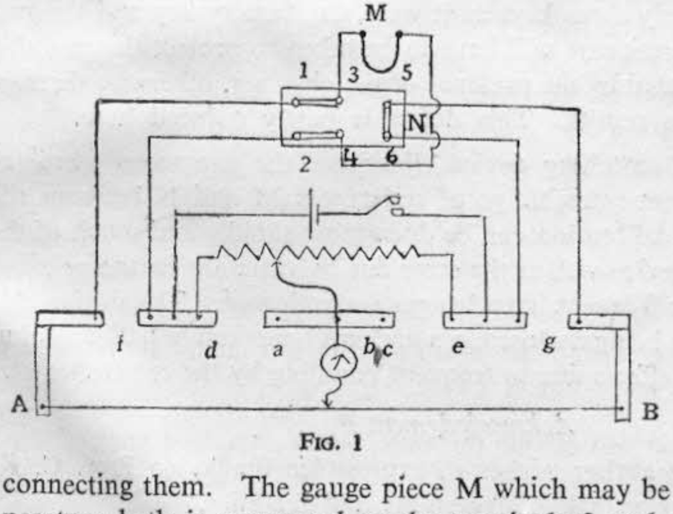

FIG. 1

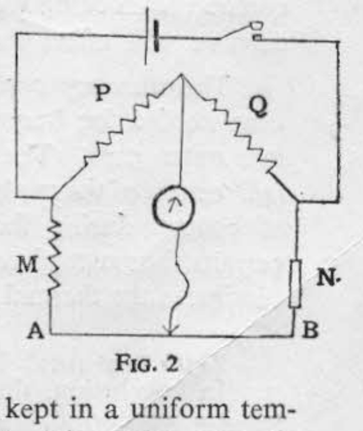

FIG. 2

connecting them. The gauge piece M which may be kept in a uniform temperature bath is connected to the terminals 3 and 4. The outer gaps are connected by equal lengths of thick connecting wires to the terminals 1, 2 and 5, 6. In one position of the switch, as shown in the figure, the gauge piece is connected to the gap f; the gap g is shorted by the thick strip 'N' thus introducing zero resistance into this gap. In the other position of the switch M and N interchange the gaps to which they are connected.

Discussion

From the arrangement it is easily seen that the sum of the resistances in the two gaps is automatically kept constant. As the sliding contact is moved—the movement is always in the same direction—the resistance included in the gap '*ad*' increases by an amount equal to the decrease in the resistance of the gap ***ce***. By the introduction of the low resistance rheostat to provide the ratio P/Q in successive steps the following advantages are secured: (1) The need for two resistance boxes P and Q as is required in some methods of calibration is dispensed with. (2) The sensitiveness of the arrangement is enhanced. (3) Further when resistance boxes are used for providing P/Q, the balance point is only approximately secured, unless some other elaborate, auxiliary shunting device is employed; the fine adjustment will have therefore to be made by moving the sliding contact. This introduces obviously an error in the calibration. In the method under discussion, such a trouble does not exist. In another method of calibrating a bridge wire, a second bridge wire is employed, the ratio arm is provided by means of a movable key. This arrangement has the same equivalent network as the arrangement under discussion. Since the two terminals of the galvanometer are connected to two movable contacts, the experimenter will have to operate simultaneously three keys as it were, the battery key and the two galvanometer keys. Great care will have to be taken to protect the movable contacts from being heated by the presence of the observer, otherwise thermo-currents will affect the results. This defect is partly reduced here.

The mercury cup switching device eliminates the enormous waste of time needed for frequent interchange of resistances M and N between the two outer gaps. The calibration can be done more rapidly and much of the tediousness of the method as well as the error due to variation in the pressure of contact during the frequent interchanges is eliminated. The device also permits the gauge piece being enclosed in a uniform temperature bath and thus eliminates the thermal effects due to frequent handling by the experimenter.

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